Journal of the Korean Society of Marine Engineers, Vol.28, No.2, pp.361~366, 2004(ISSN 1226-9549)

A Study on the Optimal Design and Forming of the Alternator Housing

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(Manuscript : Received DEC 2, 2003 ; Revised JAN 6, 2004)

Abstract : The die casting process was used to manufacture an automotive alternator housing. Generally automobile parts are required to be light and have high strength. The control of casting defects is important but has usually been depended only on the experience of the foundry engineer. Therefore simulations have been carried out on the die casting process of alternator housing. In this paper, we investigated the characteristics of the die casted alternator housing with the HPDC(High Pressure Die Casting) process. We presented the results of filling behavior and solidification process of the cast.

The analysis results obtained from the filling behavior and solidification of cast agreed with test results.

Key words : Die casting, Alternator housing, Filling behavior, Optimal design

1. Introduction

Recently the requirement of light weight and high performance automobiles has been increased. The weight of the automobile is very important from the viewpoint of fuel consumption and traveling performance. Consequently the light weight materials such as aluminum, magnesium, and titanium comes to be more important. Optimal design techniques, material techniques, process design for parts and die design techniques need to be developed for light weight automobile parts. Die casting, melted metal poured into the die cavity in conditions high speed and high pressure, is one of the best methods. Generally the die casting is considered as an appropriate forming process to manufacture the products in which complex shapes or precision surfaces are desired.

The die casting process is divided into the filling process and the solidification process. The die casting process has a series of complex temperature changes.

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Incidentally, the research by experiment must have limits because it is proceeded in the die cavity which is shut. But the research which predicts and prevents the defects of products and dies due to the shortage of the precision manufacturing and existing casting technique was possible through the computational analysis. Therefore in this study, we predicted the filling and solidification process by computer simulation and its results were reflected in the die design and the process design as a previous step for the development of the precision die of an automotive housing.

2. Simulation of die casting

2.1 Governing equation

The flow of fluid and the heat transfer phenomenon in the governing equation are represented by the mass, momentum, and the rule of energy conservation.

The governing equations used for the flow and the solidification of three dimensional incompressible flow are expressed by Eqs.(1)-(4), continuity equation(1), Navier-Stokes equation(2), energy equation(3), and volume of fluid(4).

Equation(5) shows the finite differential equation for the filling analysis.

⊙ **Continuity equation**

$$\frac{\partial u}{\partial x}+\frac{\partial v}{\partial y}+\frac{\partial w}{\partial z}=0 \qquad (1)$$

⊙ **Navier-Stokes equation**

$$\begin{aligned}
&\frac{\partial u}{\partial t}+u\frac{\partial u}{\partial x}+v\frac{\partial u}{\partial y}+w\frac{\partial u}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial x}+\nu\vec{\nabla}^2 u+g_x\\
&\frac{\partial v}{\partial t}+u\frac{\partial v}{\partial x}+v\frac{\partial v}{\partial y}+w\frac{\partial v}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial y}+\nu\vec{\nabla}^2 v+g_y\\
&\frac{\partial w}{\partial t}+u\frac{\partial w}{\partial x}+v\frac{\partial w}{\partial y}+w\frac{\partial w}{\partial z} = -\frac{1}{\rho}\frac{\partial p}{\partial z}+\nu\vec{\nabla}^2 w+g_z
\end{aligned} \qquad (2)$$

⊙ **Energy equation**

$$\rho c\frac{\partial T}{\partial t}=\frac{\partial}{\partial x}(K\frac{\partial T}{\partial x})+\frac{\partial}{\partial y}(K\frac{\partial T}{\partial y})+\frac{\partial}{\partial z}(K\frac{\partial T}{\partial z}) \qquad (3)$$

⊙ **Volume of fluid**

$$\frac{\partial F}{\partial t}=u\frac{\partial F}{\partial x}+v\frac{\partial F}{\partial y}+w\frac{\partial F}{\partial z} \qquad (4)$$

⊙ **Governing Differential Equation(GDE)**

$$\frac{\partial}{\partial t}(\rho\varphi)+\frac{\partial}{\partial x_j}(\rho u_j\varphi) = \frac{\partial}{\partial x_j}(\Gamma_\varphi\frac{\partial\varphi}{\partial x_j})+S_\varphi \qquad (5)$$

where u,v,w are the direction velocity, is the kinematic viscosity, ν is the fluid viscosity, g is the gravity acceleration, p is the pressure, and F is the volume rate of fluid.

2.2 Modelling and preprocessor

Fig.1 shows the shape model of a motor housing and is expressed using the Unigraphics as the STL file format for recognition in commercial S/W MAGMAsoft.

In the figure A is inlet and has 41181.65 ㎣ in volume, B is gate and has 179335.9 ㎣ in volume, C is ingate and has 300.7931㎣, and D is cast and has 105311.3㎣, E and F are the overflow 1 and 2 and have 171.49㎣, 3887.85㎣ in volume respectively. The motor housing shape model needs the dimensional accuracy of the average thickness 2.5~3.5㎜ within the maximum circularity 0.1 based on an inner diameter Ø100.

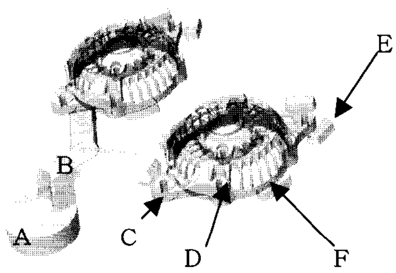

Fig. 1 3D Solid model of alternator housing.

2.3 Input of analysis condition

The material of the motor housing is ADC12 and the physical properties and chemical composition for the analysis are expressed in Tables 1 and 2. The material for the die is STD61 and water is used in cooling the channel. The melting metal, after the die is closed, is poured and we add pressure after the filling of melting metal for the strength of casting and the removal of contraction hole during the solidification process. The die is opened and products are ejected after the completion of the cast solidification, and the die is shut again after spraying the surface of the die for the next cycle to begin.

Table 1 Physical properties of ADC12 alloy.

Properties	Unit	Value
Initial Temp.	(℃)	660
Latent Heat	(KJ/kg)	514.2
Tliq	(℃)	614
Tsol	(℃)	555

Table 2 Chemical composition of ADC12 alloy.

Cu	Si	Mg	Zn	Fe	Mn	Ni	Sn	Al
3.1	11.5	0.3	0.8	0.9	0.4	0.3	0.2	R

3. Structure of the alternator housing die

Fig.2 shows the basic structure of the alternator housing die. The existing casting technique is problematic for the production of the alternator housing products in that it cannot guarantee accuracy within the maximum circularity 0.1 based on an inner diameter Ø100. For this reason, special purpose machines or general purpose lathes are required for machining alternator housings.

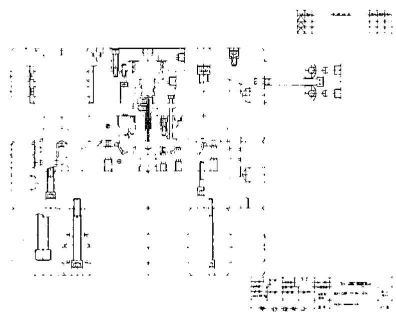

Fig. 2 Assembly drawing of the alternator housing die.

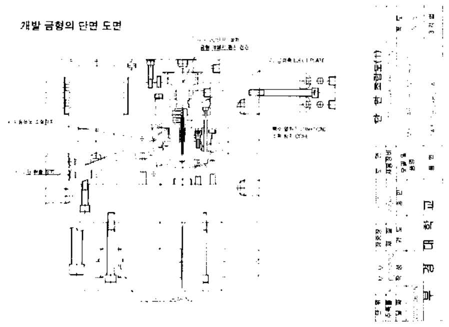

Fig. 3 A cross sectional view of the die.

To solve the problem we designed the die after modifying the machine structure to make possible the ejecting in a fixed part.

Fig.3 shows the special structure of the alternator housing die. The alternator housing is composed of a cylinder, an ejection plate, a core, a temperature controller, and an ejector.

Fig.4 expresses the forming process of the alternator housing step by step.

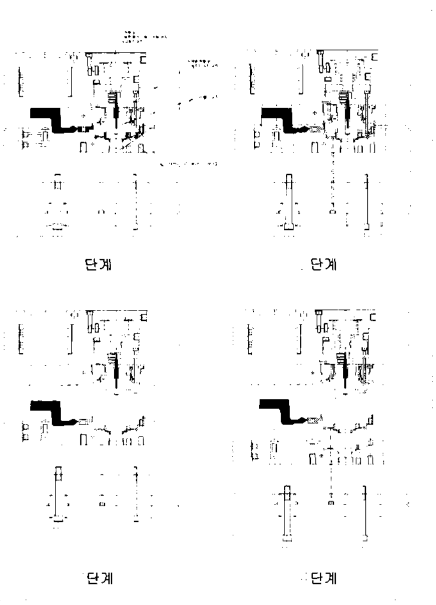

Fig. 4 Sequential steps of the die casting process.

4. Results and discussions

4.1 Filling analysis

The overall filling behavior of molten metal is shown in Fig.5. The molten metal fills in a constant filling pattern due to the housings uniform thickness design of 2.5mm to 3.5mm as was considered in the initial form design. Fig.6 shows a good filling behavior where the temperature doesn't drop below the liquid state line(Tliq=614℃).

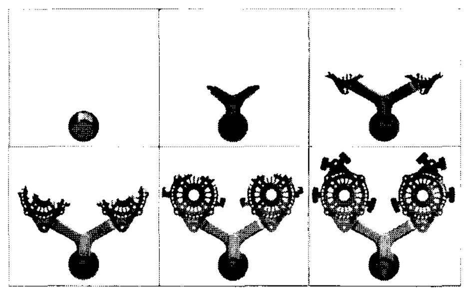

Fig. 5 Filling behavior of alternator housing.

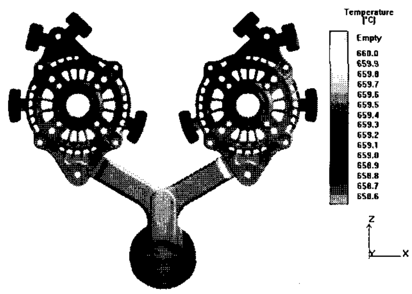

Fig. 6 Temp. distribution of alternator housing.

Fig. 7 and Fig. 8 present the time about 50% of molten metal fills housing die after the ingate is filled. The melting head collides near mark A, ingate, and it forms a vortex, and because of this, defects occurred in the part. This is considered to be because the flow of molten metal rotates at part A. The injection pressure at the ingate, as a result, is reduced and the cold shut by temperature drop and air porosity are predicted. To avoid this, we moved the parting line of the die and added the overflow at the A part. By modifying the die based on the result, we could get good forming.

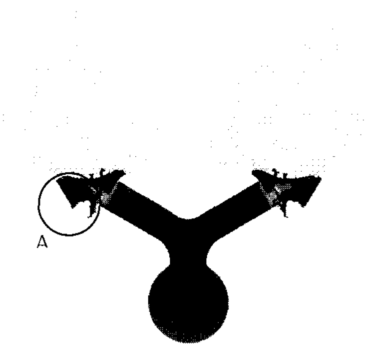

Fig. 7 Filling behavior of alternator housing.

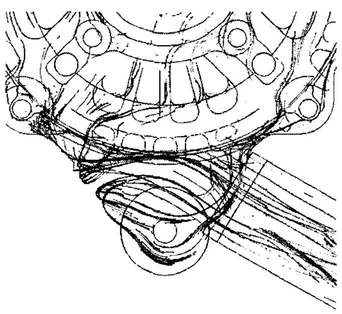

Fig. 8 Enlarged diagram of "A" in Fig.7

4.2 Final die design

Fig.9 shows the die modified with the overflow to remove the vortex of part A in Fig. 7, in accordance with the simulation results of the first design. Fig.10 shows the die made by the second design. Fig.11 shows the product formed by the second design. The filling behavior agreed with the simulation results and additional machining wasnt needed after ejecting.

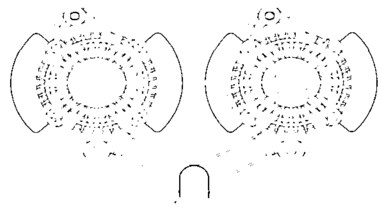

Fig. 9 Modified design of alternator housing die.

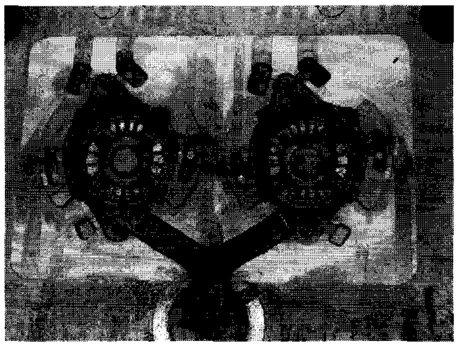

Fig. 10 Photo of alternator housing die.

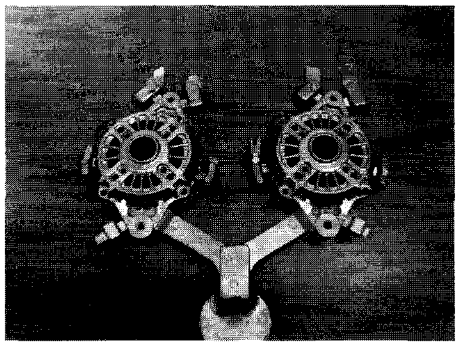

Fig. 11 Photo of alternator housing cast.

5. Conclusions

In this paper, we confirmed the filling pattern and product defects, and verified them using the commercial software, MAGMAsoft for the optimal design of the alternator housing. It is expected the effectiveness of a fixed quantity connected directly with it, will increase, such as the reduction of defects, quality enhancement, and a productivity increase due to this studys results.

The conclusions of this study can be summarized as follows:

1. The overall filling pattern expressed constant flow and the filling analysis results are agreed to the filling pattern of product.
2. The defects prediction and the analysis of the product and the die can be done using the computer simulation of the first die design.
3. The good casting product with appropriate filling pattern can be manufactured by the application of a new die design mechanism for the maximum circularity 0.1 of product.

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